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The Efficacy of Some Potassium Compound Forms on Yield, Quality, Storage Period and Control of Gray Mold Disease of Thompson Seedless H4 Grape

[1]Yasmin, A. Elsayed, [2]Magda N. Mohamed and [1]Howida A. Metwaly

[1]Central Laboratory of Organic Agriculture, Agricultural Research Center, Giza, Egypt
[2]Viticulture Research Department, Horticulture Research Institute,
Agricultural Research Center, Giza, Egypt

Abstract: The present work was done during the two successive seasons 2019 & 2020 in a vineyard located at Cairo-Alexandria desert road, Egypt, on seven-year-old "H4"a clone of Thompson seedless grapevines planted in a sandy soil under drip irrigation system. The effect of two forms of mineral potassium fertilizers at a rate of (10 cm^3 /L) were used to assess their effect on yield quality, storage period and gray mold (*Botrytis cinerea* Person) disease control of seven year-old Thompson seedless (H4) grapevine. Nine Potassium compounds treatments, bicarbonate ($KHCO_3$), carbonate (K_2CO_3), silicate (K_2SiO_3) and sulphate (K_2SO_4), whether in a water form or a gel form along with the control were evaluated in this experiment. All vines were trellised under Spanish parron system with line spacing 2 x 3 m and pruned at the first week of January. The results revealed that the treatment of Potassium silicate in both forms gave the highest values with a superiority of the gel form which can be considered a promising natural product for preharvest treatment in improving the vines quality and productivity represented in physical and chemical characteristics of berries and leaves, besides increasing the shelf life and minimizing the development of gray mold caused by *B. cinerea*.

Key words: Potassium compounds · Thompson seedless (H4) · Storage Period · Gray Mold

INTRODUCTION

Grape is gaining popularity for its high nutritive value, excellent in taste, multipurpose use and better returns. Thompson seedless grapevines H4 (*Vitus vinifera* L.) are planted throughout the world and used to produce both raisins and table grapes for the fresh market and juice [1].

Botrytis cinerea Pers. Fr. (teleomorph: *Botryotinia fuckeliana* de Bary- Whetzel), is the causal agent of gray mold in grapes that substantially reduces the yield and quality of grape production in temperate and humid regions of the world and it is considered the main pre or post-harvest decay of table grapes [2]. In berries, *B. cinerea* remains in a latent state until the post veraison (change of berry color and commencement of berry ripening) period and then resumes pathogenic development as host defenses naturally begin to decline [3]. *B. cinerea* is difficult to control because it has a variety of modes of attack, diverse hosts as inoculum sources and it can survive as mycelia and/or conidia or for extended periods as sclerotia in crop debris [4]. *B. cinerea* is a necrotrophic fungus that attacks the non-lignified aerial organs of grapes; in particular, berries are highly susceptible during ripening [5].

In recent years, use of fungicides during ripening has been subjected to increasing limitations in order to reduce or eventually eliminate chemical residues on grapes. In addition, they have negative effects on the environment and the fungicide-resistant of *B. cinerea* populations to most chemical fungicides which led to increasing the interest in using alternatives to chemical fungicides [6, 7].

It is known that table grapes are an important crop traditionally produced in Egypt. Potassium stimulates the growth of strong stems and gives the plant some disease resistance by promoting thickness of the outer cell walls. In addition, Potassium improves color, flavor and storing

Corresponding Author: Yasmin, A. Elsayed, Central Laboratory of Organic Agriculture, Agricultural Research Center, Giza, Egypt.

quality of fruits [8, 9]. Some organic potassium compounds including potassium bicarbonate, potassium carbonate, potassium silicate and potassium sulphate have been investigated as pre or post-harvest treatments by spraying grape berries which resulted in high grape quality and resistance for longer time under different conditions [10].

Potassium bicarbonate ($KHCO_3$) destroys the cell wall of a fungus by disrupting the balance of potassium ions in the cell and Potassium carbonate (K_2CO_3) had a highly inhibitory effect against *B. cinerea* even when used as pre harvest application. The effective performance of potassium bicarbonate ($KHCO_3$) was also observed in postharvest application against the development of gray mold [11]. Compounds applied in the field before harvest need long time to interact with the pathogen and grape berries, thus these compounds can affect the pathogen inocula density on the berry surface, the environment in the wound niche and probably tissue resistance [12]. Moreover, the totally inhibiting of the spore germination of *B. cinerea* at a lower concentrations during the cold storage which affected the postharvest decay particularly the early application of berry development combined with at least twice sprays which confirmed by Türkkan *et al*. [13] and Youssef *et al.* [14].

Potassium silicate (K_2SiO_3) is a highly soluble of source potassium and silica. The application of silicon has a beneficial effect in increasing the tolerance of plants to stresses as well as enhancing photosynthesis and leaf water potential, in addition to its highly effect on improvement the vine growth, yield and quality of grape cultivars [15, 16].

It was found that Potassium silicate when applied to leaves, deposits on the external surface of the leaf and acts as both physical and chemical barrier to increasing both pH and osmotic potential after water evaporation which reduce the severity of fungal diseases. The plants leaf system will rapidly bound potassium silicate in the tissue and cell walls within 24 hours of uptake. When adding silicate to a foliage spray program, it will help in lowering rate of disease attack [17].

Potassium sulphate (K_2SO_4) is also used as (K) source has consequences on yield and quality of grape. These facts indicate that SO_4 play an important role to form some proteins which ultimately has positive effect on plant growth and disease resistance. Sulphur is an important structural constituent of some amino acids such as cysteine [18].

Shelf life is important in grapes intended for table use, Gray mold is the main factor postharvest decay of grapes which leads to severe losses. this pathogen grows under cold storage and spreads rapidly from one berry to others (nesting) by aerial mycelial growth [19]. The main grapes post-harvest quality problems are decay caused by *Botrytis cinerea*, water loss, berry shatter, wilting of the cluster and shriveling of the berries [20]. Therefore, the increase in fruit shelf life and storability of the Thompson seedless H4 grapes by different potassium compounds could be explained by their positive influence in increasing fruit firmness as well as preventing fungal infections [21].

The effectiveness of gel formula with all compounds may be due to their slow evaporation, which prolongs their existence and their ability to cover the leaf surface besides breaking the surface tension caused by waxes and creating a film on the surfaces that carries moisture [22]. Moreover, the compounds nutrients in gel formulation, helps quick and easy absorption [23]. Formulation compounds with gel has been developed with long shelf-life for foliar sprays which can establish potassium compounds on leaves for longer periods to increase their efficacy with better adhesion and penetration on target site leading to control of foliar pathogens [24].

The objectives of this study were to determine the effect of using potassium obtained from different compounds (carbonate, bicarbonate, silicate and sulphate) on water or gel form as preharvest treatment, on grape quality and productivity along with its incidence on gray mold disease and shelf life of H4 grapevines.

MATERIALS AND METHODS

The present work took place during 2019 and 2020 seasons in a vineyard located on Cairo-Alexandria desert road on seven year-old Thompson seedless "H4" grapevines planted in a sandy soil under drip irrigation system. Eighty-one Thompson seedless"H4" grapevines were randomly chosen (9 treatments x 3 replicates x 3 vines / replicate). All vines were trellised under Spanish parron system with line spacing 2 x 3 m and cane pruned (8 canes x 12 buds with the total load 96 buds/vine) at the first week of January in this vineyard. The vines devoted for this work were healthy, carefully selected as being representative of the chosen cultivar and as uniform as possible in vigor and shape. Clusters in each vine were adjusted to 24 clusters for both seasons.

The present experiment included nine foliar sprays of potassium in two natural forms (dissolved in water and Gel compounds) a rate of (10 cm^3 /L) as follows:

- Water as a control treatment.
- Potassium bicarbonate ($KHCO_3$) “water”
- Potassium bicarbonate ($KHCO_3$) “Gel”
- Potassium carbonate (K_2CO_3) “water”
- Potassium carbonate (K_2C0_3) “Gel”
- Potassium silicate ($K_2 SiO_3$)“water”
- Potassium silicate (K_2SiO_3) “Gel”
- Potassium sulphate (K_2SO_4) “water”
- Potassium sulphate (K_2SO_4) “Gel”

All the treatments were sprayed at three phonological stages of berry development as follow:

At the pea size (when average berry diameter 5-7 mm), at veraison stage (when approximately 50% of the cluster berries get softened) and two weeks before harvesting. Each vine was covered completely with a film of the solutions, using a hand pressure sprayer till runoff (approximately 3L/vine). All used natural concentrated solutions of potassium compounds were prepared as stock solution at a concentration of 15 % for all potassium compounds and they are calculated according to the molecular weight or percentage of potassium in the products as K2O. The gel formula were prepared by adding 10% Carboxy-methyl Cellulose to the concentrated solutions, to increase adhesive capacity in order to enhancing plant resistance to fungal diseases and improving distribution of potassium compounds as a low release material on the surface of the treated vines [25].

The different compounds of potassium compounds were produced by The Central Laboratory of Organic Agriculture (CLOA), Agricultural Research Center, Giza. Egypt.

The Following Plant Parameters Were Determined: Representative random samples of 6 clusters/vine were harvested at maturity when total soluble solids (TSS%) reached about18 – 20 %, according to Tourky [26] and received different compounds treatments to determine the following physical or chemical components of treated clusters.

Yield and Physical Characteristics of Clusters: At harvest time 18 clusters from each treatment (3 replicates x 6 vines / replicate) were collected to determine the Yield/vine (kg), average cluster weight (g), cluster length and width (cm).

Physical Characteristics of Berries and Leaves: Average berry weight (g), berry size (cm^3) and berry firmness (g/cm^2) were calculated and leaf samples were collected at harvest time from a fruiting shoot from the basal 5^{th} to 7^{th} leaf and leaf area (cm^3) was estimated using (leaf area meter, Model CI 203, U.S.A.) at harvest..

Chemical Characteristics of Berries and Leaves: The total soluble solids in berry juice (TSS%) was measured with a digital refractometer (Krüss, Hamburg, Germany), Acidity in the juice was calculated according to A.O.A.C. [27], TSS/acid ratio of the berries.

Samples of fresh leaves opposite to the clusters at full bloom were taken to determine the following measurements:

Total Chlorophyll (SPAD): Calculated by non-destructive chlorophyll meter (MinoltaSPAD502) according to Castelli *et al.* [28].

Leaf Potassium content % was measured according to Balo *et al*. [29].

Shelf Life and Cold Storage Experiment: All the collected clusters from each treatment were divided into two groups:

- Group A which contains (9 cluster/treatment) were kept at the room temperature (24-26°C) and relative humidity (74-77% RH) for one week to emulate the local market, (the termination of experiment when 50% or more of pedicles were browning as well as when symptoms of deterioration was appeared, as wilt and shrink on different replicates) then the results was obtained.
- Group B (9 clusters /treatment) were divided into (3 clusters /box for each replicate) placed in ventilated carton box , clusters of all the treatments (27 carton boxes / treatments) were cold stored for 30 days at 0±1°C with 90-95 RH, the physical and chemical properties during the storage were estimated every 15 days intervals to determine cluster and berry characteristics as follows:

- Cluster weight loss % = (initial cluster weight – final cluster weight) / Initial clusters weight x100
- Berry decay % = Weight of decayed berries / Initial Cluster weight x100
- Berries shattering % = Weight of shattered berries / Initial Cluster weight x100
- Berry firmness (g/cm^2).
- Total loss in cluster weight% = cluster weight loss%+Decayed %+ shatter berries%
- TSS%, acidity % and TSS/acid ratio.

Isolation, Purification and Identification of the Casual Organism of Gray Mold Disease: Clusters were randomly harvested at commercial maturity from field and placed on a metal rack. Three replicates were used for each particular treatment. The pathogenic fungus was isolated from collected clusters in each treatment under laboratory conditions. Collected clusters were surface sterilized with 5% sodium hypochlorite solution for 1-2 min., then washed with sterilized water and dried between two layers of sterilized filter papers. The sterilized parts placed onto potato dextrose agar medium (PDA) and incubated at 27°C for 7 days. Developed fungus was carefully transferred to agar slants of purified fungus and stored at 5°C and served as stock cultures. Pure cultures were obtained from each of the isolated fungi using the single spore technique according to Leyronas *et al.* [30]. The fungus was identified according to their cultural and morphological characteristics as described by Khazaeli *et al*. [31].

Disease Assessment: For gray mold assessment, the evaluations on clusters were carried out 15 days after the last application. Percentage of disease incidence (DI) was determined according to the following formula:

- Disease incidence (%) = (Number of decayed clusters/Total number of clusters) ×100 [32].
- The percentage of disease severity for each treatment was determined according to disease index and scales developed by Zhou *et al.,* [33].
- Lesion area: level 0 (0% lesion area on the cluster); level 1 (25% lesion area on the cluster); level 2 (50% lesion area on the cluster); level 3 (75% lesion area on the cluster); and level 4 (100% lesion area on the cluster).

Statistical Analysis: The complete randomized block design was adopted for the experiment. The statistical analysis of the present data was carried out according to Mead *et al.* [34]. Averages were compared using the new L.S.D. values at 5% level.

RESULTS AND DISCUSSION

Yield and Physical Characteristics of Clusters: The results presented in Table (1) revealed that, yield and physical characteristics of clusters *i.e.* average of cluster weight, cluster length and cluster width were significantly affected by the conducted treatments in both seasons. Potassium silicate increased the yield and all cluster character, Moreover Potassium compounds with gel form is recorded the best effect in this aspect compared with the control during the two seasons. Similar results were obtained from Zörb *et al.* [16] who stated that potassium silicate has a highly effect on improvement the vine growth, yield and quality of grape cultivars. In addition Karimi, [35] found that potassium silicate enhances cluster dimensions by promoting synthesis and translocation of carbohydrates on grape fruits. Moreover, treating Superior grapevines with potassium silicate three times at 0.05 to 0.2% was very effective in enhancing growth aspects, yield over the control treatment [36].

In a previous study done by Abou-El-Hassan, *et al.* [25] on potato tubers, they mentioned that the application of potassium silicate in gel formula improved crop yield and quality.

Physical Characteristics of Berries and Leaf Area: Results in Table (2) show that all potassium compounds significantly improved physical characteristics of berry weight *i.e.* average berry size, berry length and berry width as well as berry firmness compared with control in both seasons. In the present study Potassium silicate with gel recorded the highest values as stated by Faissal *et al*. [36] who found that treating Superior grapevines with potassium silicate was very effective in enhancing physical characteristics of the berries over the control treatment. In addition, potassium silicate enhances berry weight [37].

Meanwhile, potassium silicate with gel formula showed the most effect of berry size at both season. Berry firmness was increased significantly with different potassium treatments especially which formulated with potassium silicate gel compared to the control which showed the lowest value. The increase in fruit firmness may be due to strong bounding of silica to the cellulose frame work and silica can only separate when the cellulose has been dissolved [38].

It is obvious from the recorded data that there are significant differences among treatments in respect to leaf area. The highest values were obtained from treating the vines with Potassium silicate in its gel form, these results may be due to the quick absorption of K with gel formula. As stated by Nikbakht *et al.* [39], there was another effect of silicon where it can increase the photosynthesis and relevant carboxylase activities as it plays a role of a mechanical and a physiological barrier, improving of the effectiveness of leaf area and photosynthetic efficiency and silicon-enhancement of photosynthesis and hypothesized that the action of silica bodies as "windows" that helped the light transmission to mesophyll area. In another trial Laane, [37] found that potassium silicate enhances leaf area.

Table 1: Yield and cluster physical characteristics of Thompson Seedless "H4" grapevine as affected by different potassium compounds treatments at both seasons 2019 and 2020

		Yield/vine (kg)		Cluster weight (g)		Cluster length (cm)		Cluster width (cm)	
Treatments		2019	2020	2019	2020	2019	2020	2019	2020
Control		10.3	12.0	430.0	501.7	21.0	19.6	13.0	15.0
Potassium bicarbonate ($KHCO_3$)	Water	13.9	14.2	578.3	595.0	21.5	25.3	15.3	17.5
	Gel	15.1	19.0	628.1	795.1	22.8	25.2	15.2	17.3
Potassium carbonate (K_2CO_3)	Water	14.4	14.0	600.4	585.0	21.3	22.3	16.7	16.0
	Gel	12.9	16.4	541.6	685.4	22.8	22.7	16.0	16.1
Potassium silicate (K_2SiO_3)	Water	15.3	15.5	637.3	646.7	22.3	24.3	15.8	18.2
	Gel	18.3	22.4	763.8	936.6	25.1	29.9	17.5	20.1
Potassium sulphate (K_2SO_4)	Water	14.5	14.4	603.1	633.1	21.6	24.1	15.5	17.6
	Gel	17.4	20.6	723.0	858.2	23.2	28.0	16.0	18.4
New L. S.D. at 0.05		0.5	0.9	30.5	41.1	1.0	1.1	0.5	0.4

Table 2: Physical characteristics of berries and leaves of Thompson seedless "H4" grapevine as affected by different potassium compounds treatments at both seasons 2019 and 2020

		Berry weight (g)		Berry size (cm^3)		Berry firmness (g/cm^2)		Leaf area (cm^3)	
Treatments		2019	2020	2019	2020	2019	2020	2019	2020
Control		1.35	2.47	1.60	2.07	171.6	195.0	152.8	155.5
Potassium bicarbonate ($KHCO_3$)	Water	1.92	2.77	1.73	2.47	215.8	239.2	163.4	167.2
	Gel	1.94	3.20	1.93	2.87	277.4	303.5	181.9	185.4
Potassium carbonate (K_2CO_3)	Water	1.88	2.60	1.67	2.27	193.6	218.3	159.7	161.2
	Gel	1.94	3.08	1.80	2.80	261.2	282.5	175.1	176.9
Potassium silicate (K_2SiO_3)	Water	1.93	2.99	1.77	2.63	279.1	302.9	181.4	188.3
	Gel	2.00	3.44	2.13	3.13	321.7	348.6	193.7	195.6
Potassium sulphate (K_2SO_4)	Water	1.92	2.93	1.73	2.63	241.5	265.7	176.6	178.1
	Gel	1.99	3.22	2.07	3.13	296.6	324.4	185.8	189.7
New L. S.D. at 0.05		0.02	0.03	0.03	0.04	21.0	20.1	2.8	3.1

Chemical Characteristics of Berries, Leaf Potassium and Chlorophyll Content: As shown in Table (3) it is apparent that all berry chemical properties *i.e.* total soluble solids (TSS%), titratable acidity and TSS/acid ratio were significantly improved by all potassium compounds with gel treatments in both seasons. Application of potassium silicate with gel increased TSS% in both seasons. Moreover, an increase in TSS% has been reported to be associated with higher levels of applied K which is helpful in the synthesis of large amounts of carbohydrates, which increase sweetness of berries. On discussing the previous results, potassium levels increased juice TSS% which could be due to the K promotion for the translocation of products of photosynthesis required for good yield and its components [40]. Moreover, it was found that grapes berries treated by Potassium Silicate 3%, presented higher levels of TSS% and lower titratable acidity [41]. Additionally, Potassium silicate application had a great effect on increasing TSS % and decreased total acidity % on Early Sweet grapevines compared with the control [42].

Also, Table (3) shows the effect of different treatments on the total chlorophyll in both seasons. It is obvious from the recorded data that there are significant differences among treatments. Potassium silicate formulated with gel gave the highest values of total chlorophyll at both seasons (38.7 and 39.9). Similar findings were obtained from Rodrigues *et al.* [17] who found that foliar applications of potassium silicate have been shown to increase chlorophyll content in 'Khoshnaw' grapevine. Moreover, Pilon *et al.* [43] cleared that silicon has played as windows allowing the light transmission to mesophyll area in addition to improving the chain of photosynthesis and preventing the deterioration of chlorophyll.

Table 3: Chemical characteristics of berries and leaves of Thompson seedless "H4" grapevine as affected by different potassium compounds treatments at both seasons 2019 and 2020

		TSS (%)		Acidity (%)		TSS/acid ratio		K %		Total chlorophyll (SPAD)	
Treatments		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Control		15.1	15.1	0.58	0.56	26.3	26.9	1.65	1.69	33.0	31.2
Potassium bicarbonate ($KHCO_3$)	Water	18.4	18.8	0.53	0.52	34.7	36.2	1.80	1.88	34.7	36.7
	Gel	19.6	19.0	0.48	0.46	40.8	41.3	2.09	2.11	36.4	37.5
Potassium carbonate (K_2CO_3)	Water	17.7	17.6	0.55	0.54	32.2	32.6	1.73	1.79	33.2	36.7
	Gel	18.6	18.5	0.53	0.51	35.1	36.3	1.97	1.96	35.9	37.1
Potassium silicate (K_2SiO_3)	Water	20.4	20.2	0.50	0.48	40.8	42.1	1.99	2.01	35.8	36.5
	Gel	22.8	23.6	0.45	0.44	50.7	53.6	2.25	2.22	38.7	39.9
Potassium sulphate (K_2SO_4)	Water	19.9	19.2	0.52	0.50	38.3	38.4	1.89	1.94	34.6	36.4
	Gel	20.8	21.4	0.49	0.45	42.4	47.6	2.19	2.19	36.2	37.7
New L. S .D. at 0.05		0.1	0.1	0.01	0.01	5.0	5.0	0.03	0.03	1.1	1.2

These results are also linear with those obtained from Faissal *et al*. [36] in a trial done on Superior grapevines. He stated that treating the vines with potassium silicate three times at 0.05 to 0.2% was very effective in enhancing leaf pigments and nutrients over the control treatment. These findings are in agreement with those obtained by Abou-El-Hassan, *et al.* [25], who illustrated that Potassium silicate formulated with gel showed the highest values of chlorophyll reading in both seasons on potato tubers.

With respect to potassium %, it is clear that K nutrient increased by the application of potassium silicate in gel form in both growing seasons (Table 3). Similarly, Uwakiem [42] found in a trial done on Early Sweet grapevines that the potassium silicate sprayed on preharvest vines was very effective in enhancing vine nutritional status specially k nutrient. Moreover, Fatima and Fadhil [44] stated that increasing the K nutrient content of the leaves when spraying French black grape cultivar with potassium silicate may be due to the positive role of silicon in improving the absorption of potassium (K+) and to its role in increasing the activity of the H^+-ATP as transporter protein in the plasma membranes of the roots, which plays an important role in potassium ion transport. Abou-El-Hassan, *et al.* [25] stated that the foliar applications of potassium silicate in gel formula recorded the maximum value of K concentrations on potato tubers.

Shelf Life Experiment

Room Temperature: Results in table (4) indicated that there were highly significant differences among tested treatments, showing a significant reduction in cluster characteristics during the storage period. Under room temperature storage , treating the vines by Potassium silicate with gel form has a positively significant effect on keeping the quality of Thompson (H4) clusters through delaying the cluster weight loss %, berry decay%, berries shattering %, the total loss in cluster weight % (Figure 1 & 2) and on the other hand increases berry firmness. These results were due to the increase in water loss % which consequently increases the weight loss % comparing with the control treatment. It was found that there was a continuous increase in these parameters gradually till the end of the shelf life. Increasing the percentage of water loss in the clusters was due to the higher evaporative potential of the surrounding air which is a strictly physical factor related to the berries water loss [45]. Similar results are observed by El-Sayed [46] who stated that weight loss percentage and shattering of crimson seedless clusters were increased during the room storage by advanced period. Also, the abscission of berries at postharvest are due to ethylene combines with the falling of auxin levels that stimulate the formation of the abscission zone at the pedicel. In addition, firmness showed decreasing values in all treatments except for the potassium silicate in gel form.

Postharvest decay caused by grey mold is extremely costly and in some cases results in the complete loss of the crop. At the wholesale and retail sectors, reducing these losses to an acceptable level remains a substantial problem for producers and marketing. During the two growing seasons under study, potassium silicate treatment (particularly in gel formula) reduced percentage of decay. Similarly, Romanize *et al.* [47] stated that Potassium silicate have dual inhibitory effects on the disease due to direct inhibition of pathogens and induction of defense mechanisms in the host tissues.

Table 4: Shelf life physical characteristics of Thompson Seedless (H4) grapevines under 7 days of room conditions in both seasons 2019 and 2020 as affected by different potassium compounds treatments

Treatments		Cluster weight loss (%)		Decay (%)		Berry shattering (%)		Firmness (g/cm^2)	
		2019	2020	2019	2020	2019	2020	2019	2020
Control		15.4	16.12	9.76	10.17	13.44	13.38	183.5	165.6
Potassium bicarbonate ($KHCO_3$)	Water	12.0	10.62	7.01	6.51	10.54	10.14	231.3	236.3
	Gel	10.9	9.76	6.13	6.00	9.58	9.19	269.0	289.5
Potassium carbonate (K_2CO_3)	Water	13.90	12.73	7.41	7.10	10.89	10.29	233.9	211.4
	Gel	10.73	9.85	6.42	6.18	10.39	9.90	265.2	276.3
Potassium silicate (K_2SiO3)	Water	11.09	9.94	5.87	5.70	8.89	8.03	262.1	258.6
	Gel	7.36	6.08	4.59	4.60	7.70	6.78	293.7	336.2
Potassium sulphate (K_2SO_4)	Water	12.67	10.87	6.77	6.62	9.23	8.96	240.2	247.8
	Gel	9.05	8.27	4.09	4.02	8.32	8.04	280.8	319.4
NewL.S.D. at 0.05		0.31	0.48	0.19	0.25	0.20	0.24	10.2	11.4

Table 5: Shelf life chemical characteristics of Thompson Seedless (H4) grapevines under 7 days of room conditions in both seasons 2019 and 2020 as affected by different potassium compounds treatments

Treatments		TSS (%)		Acidity (%)		TSS/acid ratio	
		2019	2020	2019	2020	2019	2020
Control		17.3	17.7	0.56	0.53	30.9	33.4
Potassium bicarbonate ($KHCO_3$)	Water	18.8	19.2	0.52	0.50	36.2	38.4
	Gel	19.9	20.2	0.47	0.44	42.3	45.9
Potassium carbonate (K_2CO_3)	Water	18.4	18.3	0.51	0.50	36.1	36.6
	Gel	19.0	19.1	0.50	0.49	38.0	38.9
Potassium silicate(K_2SiO_3)	Water	20.9	20.6	0.48	0.46	43.5	44.8
	Gel	22.9	23.9	0.43	0.41	53.3	58.3
Potassium sulphate (K_2SO_4)	Water	20.5	19.6	0.50	0.48	41.0	40.8
	Gel	22.1	22.6	0.46	0.43	48.0	52.6
New L.S.D. at 0.05		0.6	0.9	0.01	0.01	4.5	5.0

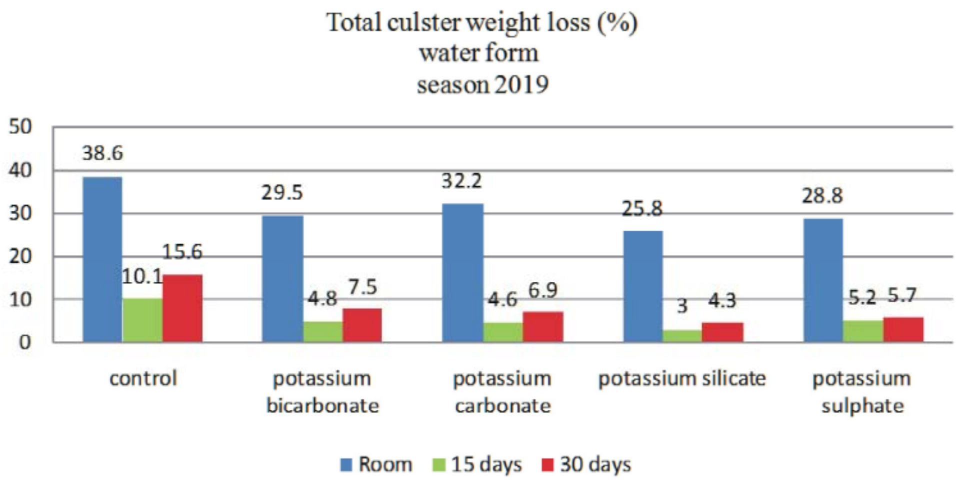
As shown in Table (5) there's a remarkable increase in the TSS % levels along the storage period under room temperature in all treatments. Accordingly potassium silicate in gel form increases the TSS % and TSS/acid ratio in berry content while it recorded the lowest values than the other treatments and the control which recorded the highest values during the shelf-life period. These obtained results were due to the increasing of water losses from the other treatments associated with respiration and moisture evaporation through the skin from the grape berries during the period of storage as illustrated by Youssef and Roberto, [48].

Cold Storage: Similarly, data taken overall the storage period of 15 and 30 days indicates that all potassium compounds in gel form treatments led to significant increase in shelf life. It is clear that Potassium silicate formulated with gel was the best treatment giving a slightly reduction in weight loss%, berry decay %, berry shattering %(Table 6) and total loss in cluster weight % (Figure 1 & 2) and recorded the highest values in the berry firmness % compared to the other treatments and the control obtained from storing at 15 days compared with the storage period for 30 days in both seasons. These results are linear with those obtained from Epstein, [49] who indicated that silicon affects crop quality, reducing transpiration rate and enhancing plant resistance to diseases problems due to the modification of cell membranes after Si application that led to reduction of water loss and subsequently reduced cluster weight loss.

Moreover, Mshraky *et al.* [50] confirmed that the exogenous application of Potassium silicate could allow alleviating the chilling injury during cold storage of different fruit species. In addition, potassium silicate led to the improvement of all quality, storage and marketing abilities and the control of postharvest diseases of grape cluster during the total storage period (5 weeks) when compared to non-treated clusters, which showed a loss of all studied properties after only 3 weeks of cold storage in two new grape varieties ARRA 15 and ARRA 18 [51]. Bassiony *et al.* [52] found that spraying Thompson seedless" grapevines with silicon compound

Table 6: Physical characteristics of Thompson Seedless (H4) grapevines under cold storage at 15 and 30 days conditions in both seasons 2019 and 2020 as affected by different potassium compounds treatments

		Weight loss %				Decay %				Berry shattering %				Firmness			
		2019		2020		2019		2020		2019		2020		2019		2020	
Treatments		15days	30days	15days	30days	15days	30days	15days	30days	15days	30days	15days	30days	15days	30days	15days	30days
Control		2.93	5.91	3.10	6.15	1.59	2.72	1.41	1.63	5.49	7.03	5.47	7.08	189.4	175.2	192.8	179.0
Potassium bicarbonate ($KHCO_3$)	Water	1.98	2.73	1.83	2.66	0.82	1.26	0.76	0.99	2.08	3.26	1.97	2.84	240.8	230.3	260.7	278.9
	Gel	1.88	2.64	1.80	2.53	0.71	1.19	0.73	0.93	1.85	3.11	1.74	2.76	282.1	263.5	331.9	314.1
Potassium carbonate (K_2CO_3)	Water	1.95	2.52	1.72	2.43	0.95	1.10	0.92	1.19	1.74	2.87	1.60	2.14	239.8	228.4	241.7	234.6
	Gel	1.80	2.43	1.67	2.30	0.89	1.06	0.85	1.15	1.63	2.69	1.53	1.99	278.1	260.7	293.6	244.8
Potassium silicate (K_2SiO_3)	Water	1.37	2.19	1.21	2.00	0.66	0.85	0.60	0.81	0.97	1.29	0.90	0.96	272.2	260.6	282.9	267.4
	Gel	1.20	1.92	1.00	1.77	0.00	0.68	0.00	0.59	0.00	0.90	0.00	0.81	307.2	289.6	340.6	331.2
Potassium sulphate (K_2SO_4)	Water	1.71	2.48	1.57	2.39	0.76	0.98	0.71	0.91	1.53	2.42	1.44	2.15	246.6	239.0	252.6	244.8
	Gel	1.62	2.31	1.45	2.22	0.79	0.95	0.65	0.88	1.41	2.08	1.30	1.90	286.0	273.9	337.0	296.9
NewL. S. D. at 0.05		0.04	0.05	0.04	0.09	0.02	0.03	0.23	0.11	0.03	0.07	0.04	0.14	2.60	4.39	2.21	4.97



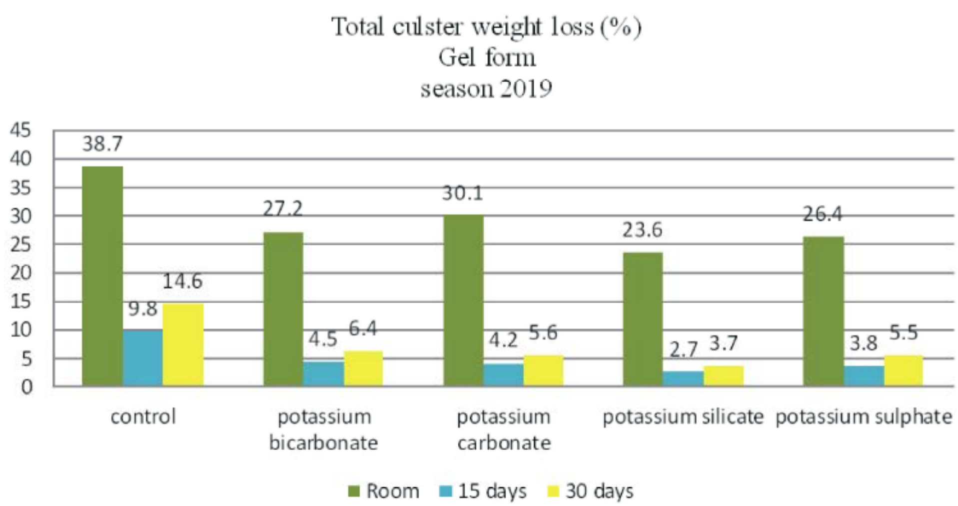
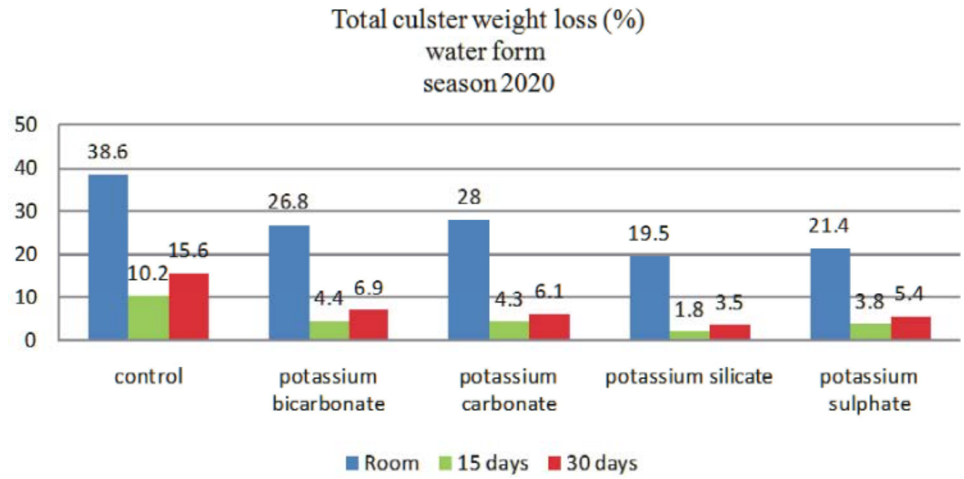


Fig. 1: Effect of potassium forms on Total cluster weight loss (%) in room temperature, after 15 and 30 days of cold storage of H4 grapevine during the successive season of the study 2019

reduced weight loss, berries shattering and enhanced berry firmness during 15and 30 days of cold storage. Abou-El-Hassan, *et al.* [25] mentioned that the application of potassium silicate in gel formula decreased the weight loss and decay percentage of potato tubers stored on the shelf for two months.



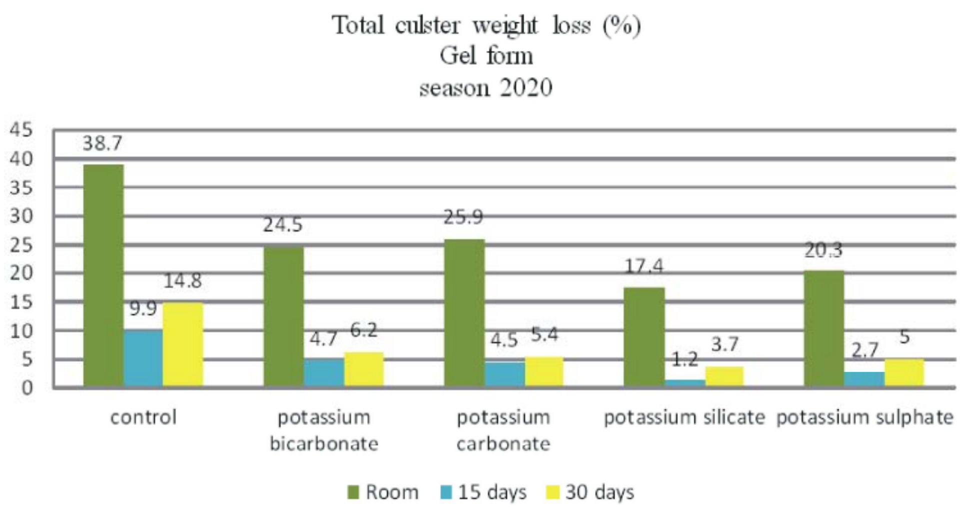


Fig. 2: Effect of potassium forms on Total cluster weight loss (%) in room temperature, after 15 and 30 days of cold storage of H4 grapevine during the successive season of the study 2020

Table 7: Chemical characteristics of Thompson Seedless (H4) grapevines under cold storage at 15 and 30 days conditions in both seasons 2019 and 2020 as affected by different potassium compounds treatments

		TSS %				Acidity %				TSS/acid ratio			
		2019		2020		2019		2020		2019		2020	
Treatments		15days	30days	15days	30days	15days	30days	15days	30days	15days	30days	15days	30days
Control		17.8	18.0	18.0	18.3	0.55	0.54	0.51	0.50	32.4	33.2	35.3	36.6
Potassium bicarbonate ($KHCO_3$)	Water	19.1	19.4	19.5	19.8	0.49	0.47	0.46	0.42	38.9	41.3	42.4	47.1
	Gel	20.3	20.6	20.8	21.2	0.44	0.41	0.41	0.38	46.1	50.2	50.7	55.8
Potassium carbonate (K_2CO_3)	Water	18.7	19.0	18.5	18.9	0.50	0.48	0.47	0.45	37.4	39.6	39.4	42.0
	Gel	19.7	20.1	19.9	20.2	0.48	0.44	0.46	0.41	41.4	45.7	43.3	49.3
Potassium silicate (K_2SiO_3)	Water	21.4	21.9	21.0	21.7	0.46	0.44	0.45	0.42	46.5	49.8	46.7	51.7
	Gel	23.4	23.7	24.2	24.8	0.41	0.37	0.38	0.34	57.1	64.1	62.1	70.9
Potassium sulphate (K_2SO_4)	Water	20.8	21.3	19.9	20.4	0.47	0.45	0.44	0.41	44.3	47.3	45.2	40.8
	Gel	22.8	23.3	22.5	22.9	0.43	0.39	0.40	0.36	53.2	59.7	56.3	63.6
NewL. S. D. at 0.05		0.3	0.3	0.9	1.0	0.01	0.01	0, 01	0.01	3.8	3.9	4.6	5.0

Table 8: Disease incidence and severity of gray mold on Thompson seedless H4 grapes at seasons 2019 and 2020 as affected by some potassium compounds treatments

Treatments		Disease Incidence %		Disease severity %	
		2019	2020	2019	2020
Control		40.6	36.3	27.7	25.3
Potassium bicarbonate ($KHCO_3$)	Water	29.3	28.2	17.8	16.8
	Gel	21.9	20.7	14.5	12.9
Potassium carbonate (K_2CO_3)	Water	31.6	29.6	18.2	17.2
	Gel	24.1	23.0	15.8	14.1
Potassium silicate (K_2SiO_3)	Water	22.2	22.3	15.0	13.3
	Gel	15.0	13.1	10.3	9.2
Potassium sulphate (K_2SO_4)	Water	26. 8	25.0	16.4	14.6
	Gel	19.2	18.0	12.2	10.7
New LSD. at 0.05		2.6	2.5	1.2	1.0

In addition, potassium silicate treatment (especially in gel formula) reduced decay % during the two growing seasons under study when compared to other treatments. Recent studies indicate that Silicon influences the effect of triggered immunity by affecting host recognition and/or limiting receptor-effect and interactions [53]. Additionally, it could be considered as one of the most promising treatment successes as alternative to traditional fungicides to control postharvest decay on table grapes.

Table (7) discussing the chemical changes during the cold storage. Obtained data revealed that treating the clusters with the gel form of Potassium silicate reduced the deteriorating effects occurred during the cold storage period concerning TSS and acidity percentage. It is clear from the data that the percentage of TSS showed an increasing values during the period of cold storage due to the continuous loss of water content of berries. In this respect El-Metwally *et al.* [54] reported that the percentage of TSS in berry juice in Crimson seedless was gradually increased as a storage period advanced at cold storage.

El-Mehrat *et al.* [51] found that spraying potassium silicate as natural preharvest treatment for ARRA 15 grapevines led to decreasing the chemical changes in juice content as higher TSS and lowest acidity less than untreated vines.

Isolation and Identification of the Causal Pathogens: The casual organism was isolated from cluster samples and they were identified as *Botrytis cinerea* Pers. Fr. which was isolated from both growing seasons.

Effect of Spray Potassium Compounds on Reduction Disease Incidence and Severity: The efficacies of testing potassium compounds under natural conditions were determined at both seasons of the study 2019 and 2020. Results in Table (8) show that all compounds treatments significantly reduced the disease incidence and severity of gray mold compared with control at both seasons. Obtained results showed that using potassium compounds formulated as gel gave better results than the same treatments as water suspension, this is due to gel create a slimy thin film surround treated leaves and improve establishment of potassium compounds on the treated surfaces [55]. The formulation with gel thus prepared as Carboxy-methyl cellulose CMC was added to potassium compounds to increase its viscosity, act as adhesive stabilizer between treated surfaces and spraying materials while , it is easy to handle and possess good efficacy with penetration on target site leading to control of foliar pathogens and assumes greater importance in crop protection [23].

Generally, Potassium compound treatments can inhibit plant pathogens or suppress mycotoxin production [56]. In another trial it was found that compounds applied in the field before harvest had a longer time to interact with the pathogen and grape berries, thus affecting the pathogen inocula density on the berry surface [48].

In addition, using potassium compounds formulated as gel creates a slimy thin film surround treated leaves and improve establishment of potassium compounds on the treated surfaces [25].

The highest reduction in disease incidence and severity were recorded with Potassium silicate treatment, as Silicon has been found to offer protection against fungal infections by strengthening cell walls, thus making it more difficult for the fungi to penetrate and colonize the plant [57].

It obvious that, the percentage of disease incidence and severity of gray mold was less in second season when compared with first season. Potassium silicate formulated with gel and suspends with water showed considerable plant protection against gray mold disease incidence and severity in the second season and recorded (13.1% and 8.6%) by gel formation and (22.3% and 13.3%) by water only. Meanwhile, the first season was recorded (15 % and 10.3%) in gel and recorded in water (25.2% and 15.0%) compared with control treatment. This may due to silicate create a thin solid film on plant tissue. This film prevents direct contact between pathogen and plant tissue. It is also known that treating plants with soluble Silica enhances fungal resistance, inhibits fungal diseases through modifications of the epidermal layer of the leaves and fruits as well as by increasing presence of low-molecular-weight metabolites [58]. Silica accumulation in cell walls was believed to be physically responsible for plant disease resistance it has a potential signal that activates defense mechanisms. On the other hand, this film reduces carbon dioxide exchange that is why this product gave protection against gray mold disease [59].

Potassium silicate the most commonly used form of Si was therefore applied in order to determine whether such practice could increase the concentration of antifungal compounds and/or the enzyme PAL to be able to increase the concentration of phenolic compounds present at later ripening stages in order to decrease disease incidence [60].

CONCLUSION

Formulated potassium compounds with gel used in this study may meet the criteria of ideal alternative means for enhancing yield, shelf life quality and controlling gray mold of H4 grapevines. Hence the treatment of Potassium silicate in gel form can be considered a promising natural product for preharvest treatment in improving the vines quality and productivity represented in physical and chemical characteristics of berries and leaves, besides minimizing the development of gray mold caused by *B. cinerea* with no fungicide residues with no possibility for the pathogen to build up any resistance. In addition to, the ease in preparation and application of the gel products, stability during transportation and storage, good shelf-life, sustained efficacy. Furthermore, It must take in our consideration the lack of studies concerning the foliar application of potassium as gel compounds on grapevines needs more researches in the future to be reviewed, thus, it seems appropriate to conduct this research.

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